CEMENT AND LIME MANUFACTURE

XV. No. 10 | OCTOBER 1942 | PRICE 1/- MONTHLY

PUBLISHED BY CONCRETE PUBLICATIONS LTD., 14, DARTMOUTH STREET, LONDON, S.W.1

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PUBLISHED 20TH OF EACH MONTH. PRICE 1/- A COPY. ANNUAL SUBSCRIPTION 12/- POST FREE

PUBLISHED BY
CONCRETE PUBLICATIONS LIMITED
14 DARTMOUTH STREET, LONDON, S.W.1

TELEPHONE: WHITEHALL 4581.
TELEGRAPHIC ADDRESS:
CONCRETIUS, PARL, LONDON

PUBLISHERS OF
"CONCRETE & CONSTRUCTIONAL ENGINEERING"
"CONCRETE BUILDING & CONCRETE PRODUCTS"
"CEMENT & LIME MANUFACTURE"
"THE CONCRETE YEAR BOOK"
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VOLUME XV. NUMBER 10 OCTOBER 1942

Types of Portland Cement.

RESTRICTIONS IN THE UNITED STATES.

IN the United States there has, during the past few years, been a demand for a large number of special types of cement for different purposes. Different Government departments and States, and even local authorities and water boards, have had their own ideas on " improved " cements, and these have frequently been incorporated in specifications. A prominent American cement manufacturer recently estimated that there were " 57 varieties " of cement, with consequent problems of separate manufacture and storage. A desire for simplification due to the war led the Government to consult the American Society for Testing Materials on the possibility of reducing the number of varieties of Portland cement, with the result that three types only are now recommended.

The new emergency specifications are designed not only to ensure greater production but to save the use of critical items such as grinding media and power by reducing the fineness requirement ; it is said that 30,000 tons of grinding media a year are consumed in the manufacture of Portland cement.

The new specifications provide for : Type I, for use in general concrete construction when the special properties specified for Types II and III are not required ; Type II, for use in general concrete construction exposed to moderate sulphate action, or where moderate heat of hydration is required ; Type III, for use when early strength is required. These correspond to Types I, II and III in the Standard Specifications for Portland Cement adopted in 1941. The new specification states that (*a*) TDA may be added to Types I and II in amounts not exceeding 0.045 per cent. by weight of the cement, and to Type III in amounts not exceeding 0.08 per cent. by weight of the cement ; (*b*) Vinsol resin may be added to Types I and II in amounts not less than 0.025 per cent. and not more than 0.045 per cent. by weight of cement. There is no change in the chemical requirements.

The physical requirements have been changed to make them easier to meet than the old requirements for Types I, II, and III, and also to reduce the consumption of power and grinding media. The old Types I and II would more than meet the new specifications except that the maximum specific surface area must not be more than 2,000 sq. cm. per gramme in any one sample. There is thus an upper limit for fineness. The minimum requirement of specific surface area is reduced from 1,600 sq. cm. per gramme for Type I and 1,700 sq. cm. per gramme for Type II (A.S.T.M. 1941 Standard) to 1,500 sq. cm. per gramme in both instances. There are no fineness limits for Type III cement.

The test for soundness by the autoclave in the emergency specification provides for a maximum of 1 per cent. expansion against ½ per cent. in the A.S.T.M. 1941 Standard.

The requirements for tensile strengths of standard mortar briquettes are the same, except that the test for specimens 1 day in moist air and 27 days in water (the 28-day test) is dropped. There are no requirements for compressive strengths in the new specifications.

The other changes are in methods of sampling. In the 1940 A.S.T.M. Standard Methods of Sampling 8 lb. samples per 400 barrels are required ; in the emergency specifications an 8-lb. sample is sufficient for 500 barrels. The time of setting is determined for each 500 barrels ; fineness and strength determinations on each 1,000 barrels, instead of 800 barrels (A.S.T.M. Standard 1940) ; autoclave expansion tests are to be made on a composite sample representing 3,000 barrels.

Soundness Test for Portland Cement.

A METHOD of determining the soundness of Portland cement is described by Mr. A. G. Larsson, of the St. Mary's Cement Co., Ltd., of Ontario, where it has been in use for five years. The author says that the autoclave method does not lend itself to routine control at his works, because too much labour and time are required, and also because too few test pieces can be handled in one treatment. In 1912 the author started the 10-hour boiling test, as it is undoubtedly more effective than the 5-hour steam test. Later it became evident that modern cement required still more effective soundness tests. From the point of view of the cement maker it seemed desirable to develop, if possible, a test that could be used for the routine-control of manufacture. It was thought that such a method ought (1) to give reliable results ; (2) to be comparatively easy to carry out ; and (3) to allow the treatment of a large number of test pieces at one time. From observations made during five years the author believes that these three aims have been closely approached by the method described.

The test is carried out in the following manner. Pats made from paste of normal consistency are used and cured for at least 24 hours in moist air. These were at first made with a trowel on 4in. by 4in. glasses, but this resulted in variations in size, form and thickness. As it seemed desirable to have the pats as

equal as possible in every respect, they have lately been formed in 3in. watch glasses of uniform depth of concavity. After curing in moist air, the pats are immersed in a bath of liquid paraffin of room temperature. The heat is then raised during the first hour to 170 deg. C. (338 deg. F.) and kept at this temperature for three hours, after which it is turned off and the test pieces taken out and inspected.

Distortion, cracking, checking and disintegration are evidently unfailing signs of unsoundness, but results of this kind can hardly be expected nowadays when the limit of expansion is set at 0·5 per cent. by the autoclave test. More delicate indications of unsoundness are therefore required. It seems reasonable to assume that any expansion stronger than the strength of the more or less hardened paste at the time of the test must form cracks, which, as functions of the reacting forces, will vary with the degree of unsoundness. The resulting cracks, therefore, might often be too fine to be visible to the naked eye. However, they will break the continuity of the mass in the hardened pat, and thus dull the tone, which otherwise would be clear. It has been found that a clear ringing tone of a pat indicates soundness and a dull tone an unsound cement, according to parallel autoclave tests on clinker, standard Portland cement, and mixtures of sound and unsound materials.

Lately, in order to approach the temperature of the autoclave test, the oil has been heated to 200 deg. C. (392 deg. F.), 210 deg. C. (410 deg. F.), and 215 deg. C. (419 deg. F.). Too few (only about 100) of these tests have been made to judge its special merits. This was not tried out before, because the results at 170 deg. C. agreed closely with the autoclave test, and also as it was feared that continuous high temperatures would break down the structure of the oil.

A few experiments also had been made to determine the tones produced in pats and bars (½in. by ½in. by 7in.). It was at first thought possible to recognise various degrees of soundness (or rather of the injurious forces of expansion) in cement, as is done in the autoclave test. The few results so far obtained are not up to expectations ; this depends at least partly on the method used in estimating the sound. But even the results from better observations might not be reliable, as the fineness of the cement seems to affect the tone. This, if confirmed, would evidently mean that any numerical estimate by the aid of the tone would not denote soundness alone, but the combined effect of soundness and fineness.

About 1,000 tests have also been made with pats treated at 338 deg. F. in the oil bath and with pats and bars treated to 422 deg. F. in the autoclave. The two kinds of treatment gave closely the same results. The oil-test was adopted some time before the autoclave method as more reliable than either the steam or boiling tests. It is used as a routine control test of manufacture, because it is easy to make and it agrees closely with the autoclave test. On account of the simplicity of the method, there is no difficulty in making the test.

Rotary Cement Kiln 475 ft. Long.

WELDED CONSTRUCTION.

WHAT is claimed to be the largest rotary cement kiln in the Western Hemisphere has recently been completed by the Allis-Chalmers Manufacturing Co., and installed at the works of the Marquette Cement Manufacturing Co. in Iowa. The kiln is 475 ft. long by 11 ft. 6 in. in diameter. It is designed to operate at a speed up to 1.33 revolutions per minute and is mounted on seven 2-roller type supporting mechanisms. The shell will have a revolving weight of 1,600 tons when loaded with refractory lining, heat transfer chains, and the cement material, and

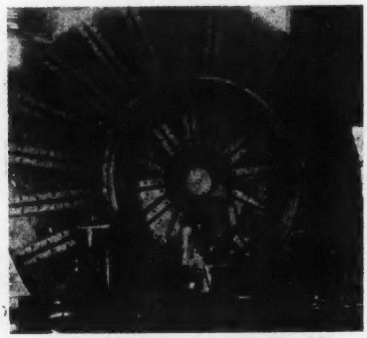


Fig. 1.—Method of Holding Riding Rings in Position during Erection.

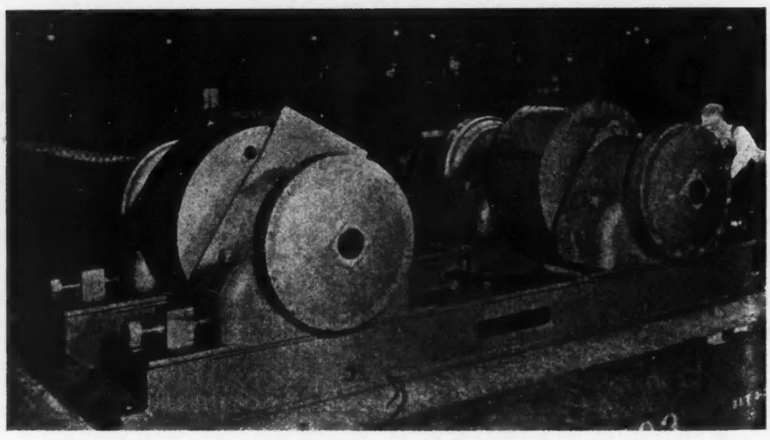


Fig. 2.—Kiln-carrying Mechanism.

is driven by a 150-h.p. motor through a double-helical type gear-reducer and totally-enclosed cut-tooth main gear attached to the shell.

It is claimed that many engineering advantages of welded construction over riveted construction are apparent, including more rigid construction with less weight, a more stream-lined unit, and lower maintenance expense on kiln elements and lining. There is a heavy solid plate construction at the riding ring courses. The riding rings are of deep box section between rings welded to the shell, permitting alternate heating and cooling of the shell without the risk of breaking rivets. The forged-steel carrying roller shafts and heavy bearings are in proportion to give shaft bending stresses of less than 3,000 lb. per square inch. Also, the

Fig. 3.—Special Discharge-end Section to Prevent Warping.

carrying rollers are narrower than the riding rings to prevent grooving. The thrust mechanism comprises heavy mushroom-type thrust rollers to carry the full downhill thrust of the kiln with bevelled thrust surfaces to minimise wear. All similar parts were made interchangeable. The bearings for carrying the roller shafts are water-cooled and flood oiled, with auxiliary oiling buckets which maintain lubrication in case the external oil supply fails.

Anti-slip bars are welded to the interior of the kiln shell to prevent slipping of the refractories, while a special air-cooled discharge end section prevents the shell from warping even under conditions of high temperature of secondary air.

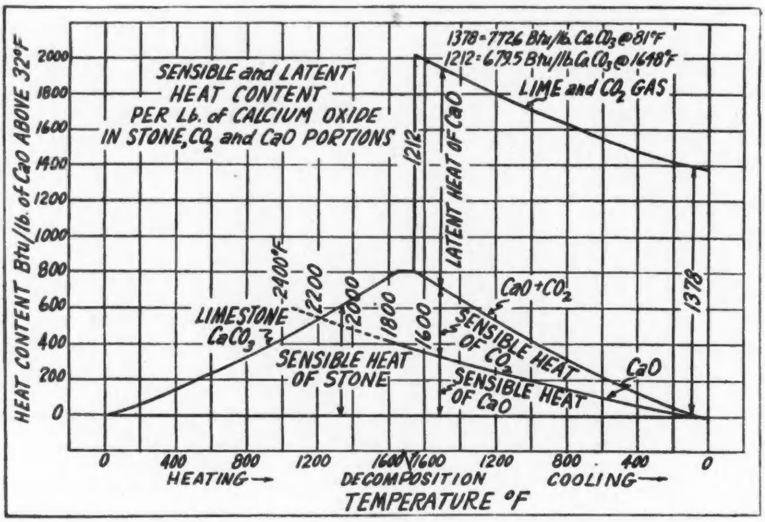
Welding operations on the kiln were not completed until the new unit had reached the cement works. Maximum permissible clearance made it necessary to weld anti-distortion rings where absolute rigidity of the shell was necessary.

The Efficiency of Lime Kilns.

SOME of the difficulties encountered in any attempt to calculate the efficiency of a lime kiln are discussed by Mr. V. J. Azbe in a recent number of *Rock Products*. The customary procedure is, he states, to assume that the theoretical kiln will have a cold top and a cold bottom, will lose no heat by radiation, and that the only way in which it will utilise heat from the fuel is in dissociation of carbonates. The basis that has been used is that 1,378 B.T.U. were required for each pound of CaO and 1,215 B.T.U. for each pound of MgO. The method is as follows:

$$\frac{\text{CaO in lime} \times 1{,}378 + \text{Mgo} \times 1{,}215 \times \text{Ratio}}{\text{Heat value of one pound of coal}} \times 100 = \text{Per cent. efficiency.}$$

By this method of determination 100 per cent. efficiency would mean a ratio better than 10 to 1 with fuel of 13,780 B.T.U., as 1,378 B.T.U. are needed for



dissociation of carbonate to one pound of calcium oxide. With dolomite the ratio would be slightly higher. Unfortunately there are innumerable complications, due in part to the fuel, to the lime, and to the kiln.

The stated heat value is not the available heat value. The 1,000 B.T.U. per cubic foot of natural gas is actually only 900 B.T.U. gas. In the calorimeter it produces 1,000 B.T.U., since moisture from combustion of hydrogen would be condensed and its latent heat released, but that cannot take place in any lime kiln. If, on the other hand, the fuel is coke, due to its very low hydrogen content almost the full calorimeter heat value will be produced in the lime kiln and be available in sensible form. Even of this, the ideal theoretical kiln could not use all.

If such a kiln cannot use all of this heat, why should we blame the kiln and give it a lower efficiency than is just, and blame it for failing to do something which it is not in its nature to accomplish ?

Another discrepancy is brought about by the fact that a kiln ordinarily considered as one unit consists really of three entirely distinct units, each having a different duty to perform. In one the stone is pre-heated, in the next it is calcined, in the third the lime is cooled. Each of these operations has its own operating efficiency that could be determined if the zones did not run into each other. This intermingling not only makes it impossible to gauge exactly the performance of the different zones but, when lime contains magnesium, makes even the determination of overall efficiency nearly impossible.

The efficiency of a kiln should be evaluated on the basis of the heat of the fuel theoretically retainable in the kiln, together with the expectation that the kiln will do its theoretical utmost to utilise this heat. But what is this theoretical utmost ? Heat from fuel can be divided into four portions : (1) Heat available for calcination of $CaCO_3$—" high heat "—1,650 deg. F. and up ; (2) heat available for calcination of $MgCO_3$—" medium heat "—1,400 deg. F. and up ; (3) sensible heat available for pre-heating of stone—" low heat " ; and (4) heat unavailable to either—" latent heat." As there is more low heat than there is stone to absorb it, part of it is certain to escape, and that is no fault of the kiln. It is of no use expecting a kiln not to use any of the higher heats for any of the lower purposes. For example, it is unreasonable to expect that no heat higher than 1,650 deg. F. be used for preheating of stone ; if the stone were all in small sizes, say 1 in., the expectation would be more reasonable, but when stone is 6 in. or 7 in. in minimum dimensions the medium or high heat that calcines the outside also preheats the inside. Then while the outside, which is exposed to kiln atmosphere of about 30 per cent. CO_2, starts dissociating at 1,515 deg. F., the inside has a higher CO_2 concentration up to 100 per cent., at which dissociation takes place at 1,650 deg. F., provided there is no back pressure. What should be taken as the dividing point between calcination and preheating zones, 1,515 deg. or 1,650 deg. F. ? The writer prefers the higher figure, as most lime is dissociated at that level, but the theorist may counter by saying beginning is beginning, and 1,515 deg. is what should count.

While we could arbitrarily assume that in the ideal kiln the terminal temperature is zero at the end of each zone, either 1,650 or 1,400 deg. F. depending on whether it is the junction of the calcium and magnesium or the beginning of the magnesium zones, that would not be fully satisfying. On the other hand, we should know what is the temperature difference between the lime and the gas stream, and what it is through the lime and the limestone. With that information we then determine (a) how much heat of higher value is lost due to imperfection of external heat transfer, and (b) how much is lost due to resistance to internal heat transfer. To determine all this is impossible, for there will be differences with different stone sizes and shapes and differences with different gas flow rates, also due to differences of exposure and packing of individual pieces.

The magnesium carbonate of dolomite demands a lower temperature for dissociation and also requires less heat. This is readily taken care of, but as magnesium carbonate dissociates 250 deg. F. lower than calcium carbonate, much of it dissociates before calcium carbonate begins to dissociate. Therefore much of the magnesium carbonate is calcined with waste heat from the calcium carbonate calcining portion of the kiln. To calculate the efficiency of a kiln calcining dolomite as we would a high-calcium limestone kiln by mere heat requirement, as the formula given at the beginning demands, would favour the dolomite kiln to the disadvantage of the high-calcium limestone kiln. The question is how to determine how much of the magnesium carbonate portion is calcined with medium heat of between 1,400 deg. F. and 1,650 deg. F. and how much slips by into the higher section and is there calcined with heat over 1,650 deg. F. which otherwise would have been used for dissociating calcium carbonate.

The next problem is what is the heat capacity of the products of combustion plus the CO_2 from the lime leaving the calcium carbonate and entering the magnesium carbonate portion of the kiln. Of the heat in the products of combustion we can be sure, in the theoretical kiln anyway, but that is not the case of heat in the CO_2 from the stone, because it is difficult to determine the amount of CO_2 that is lime that will be made. The theoretical ideal discharges lime at the same temperature as the air that enters the cooler, and the heat from the cooler returns to the hot zone to make lime. But lime in the cooler is not just lime of an equal heat capacity. The core brings heat into the cooler and that heat later makes some lime. Magnesium oxide has a much higher specific heat than calcium oxide and is therefore an important converter of low heat in the preheating zone into high heat.

The impurities must also be considered. With impure limestones surprisingly high ratios are often obtained, but that does not make the kilns any more efficient —calculating the efficiency in a manner that would take everything into consideration would show that up quickly. Taking silica, for example, any given amount reduces the carbonate by an equal amount, and the heat required for calcination is reduced proportionately. Then the silica combines with the lime, and that is a heat-generating reaction. In addition, the silica absorbs some low heat in the stone preheater, and that heat is delivered in the cooler and from there returns to the calcination zone to serve as high heat in making the lime. A study indicates that the heat of combination of silica with lime is about proportional to the amount of silica regardless of the kind of combination it enters into. In all, the reduction of heat requirement in lime kilns for each per cent. of silica in lime will be about 27 B.T.U., consisting of the following separate items :

	B.T.U.
Reduction in heat of dissociation through displacement	13.8
Heat of combination (formation of calcium silicates)	9.5
Regenerative effect (heat reversion by cooler)	3.9
Total	27.2

So each per cent. of silica in lime reduces fuel requirements about 2 per cent., and with alumina and iron the same would apply although quantitatively different. But while the fuel requirement is reduced, that does not mean that efficiency is increased and that a high-ratio lime kiln burning impure stone may be little more efficient than a low-ratio lime kiln burning pure stone, contrary to appearances. That it is a little more efficient is due to the regenerative effect. To obtain the many factors necessary is not simple. The figure given only gives part of the information, and heats of reaction and specific heats of the various substances that enter into consideration must be those at high temperatures prevailing in the kiln.

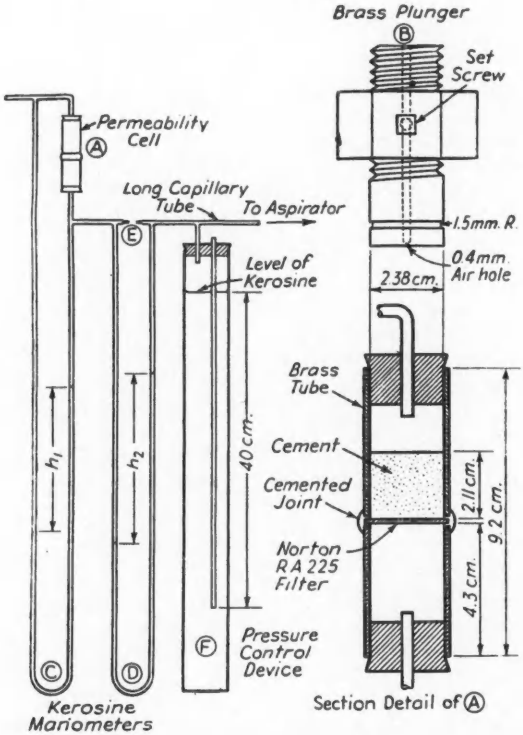
It is important to determine efficiency precisely because kilns are reaching toward the limit, and so we should know exactly what is the limit. On the available heat basis some kilns operate now with an efficiency in excess of 80 per cent. and are still improving. Considering that about 10 per cent. of the remaining heat is radiation loss counted as avoidable but to a great extent unavoidable, there is only about 10 per cent. waste heat left to work on.

Five thousand cubic feet of 1,000 B.T.U. natural gas means an efficiency of 75 per cent. on available heat basis, and only 55 per cent. when calculated on total heat basis.

Air-Permeability Measurement of Specific Surface.

THE air-permeability apparatus shown in the accompanying drawing is being used by the United States Bureau of Standards to determine the reproducibility of results obtained on Portland cement by different operators and the applicability of the apparatus to other materials, and to compare the relative specific-surface values obtained by the air-permeability method described by Lea and Nurse with those obtained by the Wagner turbidimeter.

The apparatus is similar to that used by Lea and Nurse. The permeability cell (*A*) was made of 1 in. (outside diameter) brass tubing and had an inside



Air-permeability Apparatus for Measuring Specific Surface.

diameter of 2·38 cm. compared with 2·54 cm. for the Lea and Nurse cell. The filter disc (Norton porous filter *RA* 225) sealed between the upper and lower parts of the cell with Duco cement was used in place of a perforated metal disc and filter paper. The outside edge of the filter disc was also sealed to prevent leakage. The plunger (*B*), used to compact the powder in the cell to a definite

volume, had an adjustable collar with a set screw. The plunger was made to fit snugly the inside of the permeability cell. The manometers (C, D), 50 cm. long and half filled with kerosene, were used to measure the pressure drop across the bed of cement and that across the capillary respectively. The capillary tube (E) was made of four 3 ft. lengths of capillary tubing having an average internal diameter of 0·675 mm. This average diameter was calculated from the weight and length of a column of mercury in the capillary. The value reported is the average for each of the capillary tubes. The several lengths were connected in series with rubber tubing and sealed with a resin-paraffin mixture. The capillary was calibrated against a flow meter at pressures of from 4 to 27 cm. of kerosene.

The appropriate weight of powder was placed in the permeability cell and levelled by gently rapping the sides. The powder was then slowly compressed by means of the plunger until the plunger collar was in contact with the top of the cell. While pressure was maintained on the plunger it was rotated one complete revolution and then withdrawn slowly with a rotary motion. Any powder adhering to the sides of the plunger or any which had been forced into the plunger vent was returned to the cell and the bed of powder again compressed as previously, and the plunger withdrawn slowly. The cell was then connected to the apparatus and the pressure difference applied. Manometer readings were taken 5 minutes after air flow was started. Calculations of specific surface were made with the same assumptions and the formula proposed by Lea and Nurse.

Determinations of the resistance of the filter alone were made after every four determinations of fineness. The filter disc was cleaned with HCl after each 20 determinations, or more often if the condition of the filter disc required it. Its resistance was about 1 per cent. of the resistance of the capillary; hence corrections were not made on the results here reported.

In discussing the results, Mr. R. L. Blaine, assistant engineer of the Bureau, states that in any test method, simplicity and reproducibility of test results are desired. The air-permeability apparatus is simple to operate, and there is little likelihood of a failure of any of its parts other than by breakage. The results of duplicate tests by one operator or by a number of operators show good reproducibility. The time required for making a test is short (8 to 10 minutes), and the apparatus is therefore suitable for plant control work. On the other hand, it was noted that slight differences of specific-surface values were obtained by varying the rate of air flow through the same bed. Testing very fine materials such as hydrated lime at various porosities indicated that there is probably an agglomeration or a channelling of particles tending to result in low specific-surface values with high porosity. However, at any one porosity and rate of flow of air the results were reproducible. If the apparatus is to be used for specification purposes, it may be necessary to specify for any given material the rate of air flow through the bed as well as the area, depth, and porosity of the bed.

Although the specific-surface values obtained by the air-permeability method are at variance with the results obtained by the turbidimeter, the two methods

are based on different primary assumptions and each method is essentially a comparative one. Certain behaviour characteristic of Portland cement seem to indicate that the values of specific surface obtained with the air-permeability method are closer approximations of the true values than are obtained with the turbidimeter. However, the determination of absolute values of surface areas of irregularly shaped granules will require further study. The apparatus affords a ready means of comparing the specific surfaces of powdered materials. The procedure is fast and simple and the test results are reproducible. The air-permeability apparatus is well adapted to test materials of the fineness of Portland cement, and can be used for testing finer materials. The apparatus can be used to determine the specific surfaces of mixtures of two or more components having different specific gravities.

Emergency Repairs and Maintenance.

IN view of the increasing difficulty of getting new plant and spare parts for cement plant, our United States contemporary *Rock Products* has published a number of suggestions on emergency means of repairing and maintaining plant. Some of these are summarised below, as submitted by cement works managers and others.

Cracking of Compartment Mills.

A large compartment finish mill of conventional design cracked over half way around the shell between the second and third compartments. The crack was V'ed out and welded. New plates were prepared and welded to the shell. These new welded plates just filled the spaces between the existing butt straps, so that the mill had a double shell over the repaired section. About two months later a similar compartment mill broke in the same manner, and was repaired in the same way. Both mills had been in operation about ten years prior to the development of these major cracks.

With both mills having a double shell in their central sections, equal to about half the length of the mill, it was felt that lasting repairs had been accomplished. This, however, was not to be the case, for recently one of the mills has again broken near the original repair, and this time the cracks have formed not only in the original mill shell, but in the new plates welded to it. Another welding job has been effected, and the mill is running, but it is apparent that a type of repair more fundamental than continually welding up cracks will be required to keep these mills from breaking in two.

Inquiries made of other operators who have similar large compartment mills have revealed that cracking of such mills is occurring all too frequently. Lasting repairs, in some instances, have been made by installing riding rings near the centres of the mills. These rings are supported by rolls which carry the load at the middle point of the mills. In some cases the rolls rest on a rigid foundation, and in other cases spring supports are provided for the roll foundations. This procedure would appear to be the most advisable, because it provides constant support at the rolls regardless of factors such as wear of trunnion bearings and

warping of the mill shell due to temperature effects. In other instances repairs have been made by welding bars to the mill shell parallel to its axis.

While repairs such as these serve to keep these large mills in operation, it is apparent that their basic design has been at fault. It may be that long and heavy tube mills, supported only by end trunnions, are not practicable.

Speed of Compartment Mills.

Experience shows that manufacturers of grinding mills do not agree on mill speeds, ball loads or ball sizes for preliminary and final grinding. It is desirable that further research work be done on this to establish the best operating practice. The compartment mills at one cement plant were equipped with sling type or "cradle feeders." These feeders were not positive enough, as the amount fed would vary greatly due to variations in the size of the clinker handled. There was no way of gauging the amount of clinker being fed. This condition has been corrected by installing constant-weight belt feeders, with substantial improvement in mill capacity.

Kiln Refractories.

Most of our kiln lining failures start on the butt-straps of the kilns, where the rivets are, as this is the place where the kiln shell first shows red. We are now experimenting in the back zone in an attempt to prolong the life of the magnesite bricks over the rivets. In a section where we normally use silica bricks we have continued the silica bricks except over the riveted portions, where we have used high-alumina brick. This experiment has not yet continued long enough to tell if the results are favourable.

Welding.

Our welding machine has been nearly " worth its weight in gold." The job on which the welder saved most was a hopper for a large crusher. This hopper is of 1-in. steel plate heavily reinforced on the underside. The abrasion of the stone wore the plate through, and while half the hopper was good the remaining half was worn out. We resorted to the electric welding of 1-in. by 6-in. bars on the worn surfaces three years ago. Since that time we have added each year another layer of 1-in. by 6-in. bars, and so far have been able to postpone the installation of a new steel hopper.

We have resorted to more electric welding to harden surfaces on equipment, such as fan liners and blades, dipper teeth, and hammers for secondary crushers so that we get a much longer life on this equipment.

Sintering Ore in Rotary Cement and Lime Kilns.

THE possibility of using rotary kilns in lime and cement plants near to ore deposits for sintering ore (which is a method of concentrating it, or making it more suitable for the blast furnaces or smelters) has been dealt with by Mr. S. G. Thyrre, vice-president of Messrs. F. L. Smidth and Co., of New York.

Mr. Thyrre states that the plain rotary cement kiln is not at all suited for this work, due to the tendency of the material in the kiln to stick to the lining, until the condition illustrated in Fig. 1 arises. Unless the lower part of the kiln and the fire control are especially designed for ore sintering, the removal of the lining ring is too difficult and expensive. The object is to shorten and enlarge the sintering zone and provide a suitable mechanical device for removing the rings or lining coatings.

The device for removing the coating is a powerful water-cooled boring bar, equipped with a cutter and mounted on a heavy carriage. In sintering iron ore

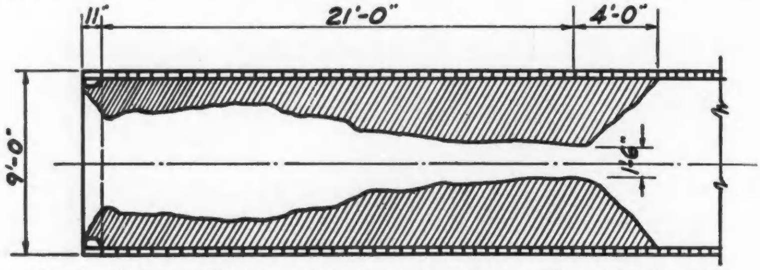


Fig. 1.—Shape of Ring in a 9-ft. by 175-ft. Rotary Kiln after Sintering Iron Ore for a Few Days.

this boring machine is used for ten to fifteen minutes once or twice in an eight-hour shift.

An important feature in connection with the design of the hood is the water-cooled lining plates on which the hot and sticky material from the kiln is discharged. The water cooling of these lining plates prevents adhering of the material to the liner plates. From the hood the material is discharged on to a cooler in which the air for combustion is utilised for cooling the product, the air thereby becoming pre-heated to a considerable extent.

The Cuban American Manganese Corporation installed a 213-ft. rotary kiln for sintering wet manganese concentrates in 1936. The Victor Chemical Co. has a wet process kiln of approximately the same size as that at the Cuban works, installed about three years ago, for sintering low-grade phosphate ore. This material in the sintering zone is extremely sticky, which necessitates using the boring bar more frequently. The feed contains about 25 per cent. of free water, and the fuel for the kiln consists of CO waste gas from the electric furnaces in which the pure phosphorus is produced. The Anaconda Copper Mining Co. has a larger kiln of the same type for sintering manganese flotation concentrates.

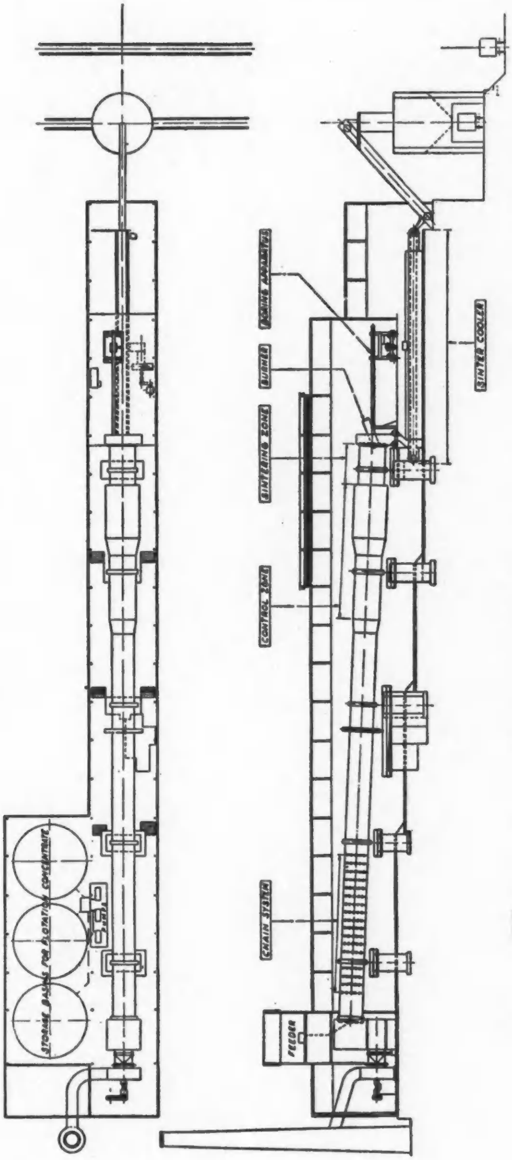


Fig. 2.—Design for Rotary Kiln Installation for Sintering Ores which adhere to Lining.
(See page 162.)

Unit Coal Mills for Shaft Lime Kilns.

A LIME works which has been firing successfully, for the past three years, four shaft kilns with unit coal pulverisers and induced draught is described by Mr. B. Nordberg in a recent number of "Rock Products." No two kilns are alike, being cylindrical and oval in shape, and the No. 1 spall kiln burns spalls down to 1 in. in size. This kiln has a "corkscrew" lining to keep the small stone from packing. All were originally designed for natural gas firing. With direct firing by coal the fuel ratio (lime to coal) has been increased by more than 25 per cent. over natural gas, and average fuel ratios of from $5\frac{1}{2}$ to 6 tons of lime to a ton of coal are claimed.

The coal pulverisers are very small hammer mills, one being used to fire each side of each kiln. They are arranged in two banks of four, each bank serving one side of the four kilns. Each mill has a separate coal hopper, and all are in a line parallel to the coal track and main storage area outside the plant. The hoppers are filled by hand-shovels, and feed to the mills is through revolving-plate feeders. The mills are driven at 3,450 r.p.m. by separate 3-h.p. enclosed motors, and are a type commonly used for firing steam boilers. In normal operation each mill pulverises 135 lb. of coal per hour to the desired fineness. The hammers are 2 in. square and have a life of 150 tons of coal pulverised before changing hammers; the hammers are of high-manganese steel. With new hammers, coal is pulverised to about 85 per cent. through the 200-mesh sieve with a progressive falling off in efficiency as the hammers become worn. The raw fuel feed is $\frac{1}{4}$ in. minus screenings with a heat value of 12,190 B.T.U., 3 per cent. ash, and very little sulphur.

In converting the kilns to burn pulverised coal in place of natural gas, fire boxes were added with the idea of using them as combustion chambers to catch the ash. However, the kilns did not operate successfully on that arrangement and the fire boxes serve little useful purpose now except to cover the large open arch, which drops out the lime on which ash has been deposited. The feed of coal into No. 1 kiln from each coal mill is through two $2\frac{1}{2}$ in. diameter burner pipes, and the other kilns are fired through a single 3 in. diameter burner pipe from each mill. The burner pipes are stopped short about 2 ft. from the fire arches in the ovens. The burning zone is about 6 ft. high above the arch or burner pipe. The arches are left open so that the exposed lime surface will catch the coal ash deposited from the end of the burner pipes.

The kilns are 55 ft. in height with a shell diameter of 12 ft., and have a maximum capacity of 25 to 30 tons of lime per day. They are charged in the conventional manner by pulling side-dump trucks up an incline.

To make the induced draught effective to the greatest degree, the kiln tops have been sealed with 5 ft. by 7 ft. rectangular slide tops which are opened only when charging the kilns. Induced draught is provided for each kiln by a fan direct-connected to a 10-h.p. motor. Gases are drawn through 20 in. diameter piping by the fan and discharged into the atmosphere at 250 deg. to 500 deg. F. Each kiln has a damper to control the draught, and its operation is controlled from an instrument room on the main firing floor.